# FACTORY CHEMISTRY

## PREPARATORY TO COURSES IN METALLURGY AND METALLOGRAPHY

SR

BY

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# PREFACE

THIS text is especially designed for factory men interested in the study of Chemistry as it bears on the various operations in factory processes, presenting by simple, clear, and rapid methods, only that part of Chemical Science which will be of daily use and practical value in such departments where a knowledge of Chemistry is of advantage and often indispensable. The subject matter has grown out of a necessity for a special course in Chemistry, treating more than is customary upon symbols, valence and chemical reaction, fitting the men for specific work where Chemistry is involved. Taking in order the elements, Valence, Atomic Weights, Oxids, Hydrates, Acids, their properties, how they act and react upon each other and the expression of these reactions in Chemical formulae as shown by the chemical equation, preparing them, in a comparatively short time, to take up work in Qualitative Analysis as a laboratory course. After this is completed thoroughly, the student is ready for work in Quantitative Metallurgical Analysis. .

The work is not to be considered in any sense as an exhaustive treatise on General Chemical Science, but, while recognizing the great laws of Chemical Science, their special application and adaptation to factory demands seem to require such treatment that will illuminate and assist in various ways the particular work of each man wherever he may be placed, and as such we hope its mission will be fulfilled.

WILLIAM H. HAWKES.

DETROIT, MICHIGAN,
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# FACTORY CHEMISTRY

# INTRODUCTION

MATTER is what we see about us everywhere in an endless variety of substances. Scientifically stated, **matter** is anything that has weight and occupies space. Matter comprehends all substances; each different substance has its own composition. If we separate this substance into its component parts, each part is called an **element,** and the material of this part is an **elementary substance,** or it is that material that cannot be changed into any other substance.

The number of elementary substances known to exist is about eighty, but of these the greater part is found rarely and in very small quantities. The common materials of substances in common use are formed from less than thirty different elements. The largest number of elements called into use in the ordinary manufacturing plant is about forty-five.

The table of elements gives the names, symbols, valence, and atomic weights of all elementary substances to be met with in ordinary chemical processes. The symbols, valence, and atomic weight of each element should be thoroughly committed to memory.

The smallest possible amount that can enter into chemical combination with another substance is termed an **atom;** atoms combine with others to form **molecules;** molecules combine to form **substances.** The force that holds them in chemical union is **chemism,** or chemical affinity. Little is known about this mysterious force except that it exists, and that it acts in accordance with well-known laws in a manner like electricity, and it is possible, as is shown by many experiments, that the atom is inhabited by still smaller entities called **electrons** that swarm about inside an atom like bees inside of a church room or hall. The comparative size of an electron can possibly be imagined when we consider the size of an atom to be about 1/200,000,000 of an inch in diameter.

If a substance dissolves in a liquid, the liquid in which it dissolves is called a **solvent,** the dissolved substance is called the **solute,** and the two combined is the **solution.**

When a solution is exposed to the air and it gradually diminishes in bulk till it "dries up," it is said to **evaporate,** and the process is called **evaporation.** The solute does not evaporate, but is left behind as a deposit, usually in the form of **crystals.** The more rapid the evaporation the smaller the crystals. The molecules of a crystalline substance are believed to have a symmetrical arrangement. Molecules without this arrangement are called **colloidal** and the substances are **colloids.** Another name for a substance not crystalline is **amorphous.**

A substance that vaporizes at ordinary temperatures is called **volatile.** Heat hastens the process. This term is usually applied to solid substances, as Iodine.

The vapors from a volatile substance coming in contact with a cooler surface condense back to their original form and are then said to sublime, and the deposit is called a **sublimate.**

When a simple substance or an element unites with oxygen, either of the air or pure oxygen, it forms a class of compounds called **oxids.**

## VALENCE

**Laws of Valence.**—When a chemical union takes place between two or more substances it does so in accordance with certain laws of combination. This means that when these substances unite they do so only in definite proportions or amounts. There is no variation. These laws are called the laws of valence, or the combining power of an element compared with that of an atom of hydrogen. Hydrogen is taken as a standard of combining power. If one atom of a substance combines with only one atom of hydrogen, it is called **univalent**; if it will combine with two of hydrogen, it is **bivalent**; if with three, it is **trivalent**; if with four, **quadrivalent**; if with six, it is **hexavalent.** If one atom of one substance unites with an atom of another substance that has the same valence as hydrogen, it is said to have the **hydrogen equivalent** of combining power.

**Table of Valences.**—In the table of valences the elements are arranged according to their valence. Groups of atoms acting as a single atom also have valence, and are given in each list after the elements.

In applying this list of valences, any element or radical is equivalent to or will displace as many atoms of hydrogen as is shown by the valence of the element. If more than one valence is shown, either valence may be used, the conditions of the reaction to determine which one.

On account of the great value and importance of valence in understanding the formation of formulas representing the composition of molecules, we have, for the convenience of the student, arranged the elements to be used in this book in the form of a table according to their valenc shown on page 14. From this table he will see at a gla all the elements that are univalent, bivalent, trival quadrivalent, etc., and those that have more than valence and what the valences are.

The numbers at the top of each column indicate valence. Besides the valence of the elements ther also given the valence of combining radicals correspo ing to the valence of the elements.

**Operative Rules for the Use of Applying Valence** When the valences are the same in each of the combi parts, the parts unite with but one atom, or grou atoms in each part, each to each.

*Examples:*

| | |
|---|---|
| $H+Cl=HCl$ | Valence 1, Element with Eleme |
| $Ba+O=BaO$ | Valence 2, Element with Eleme |
| $Ba+SO_4=BaSO_4$ | Valence 2, Elements with Radi |
| $Al+PO_4=AlPO_4$ | Valence 3, Elements with Radi |

We see in each of these examples that only one ato part is united with one atom or part, each to each.

When the valences are different in each of the combi parts, but one is a multiple of the other: the part with lower valence will have as many atoms as its valenc contained times in the higher valence.

*Example:*

$$Hg+2Cl=HgCl_2$$

Here Hg is bivalent and Cl univalent or 1, so that take 2 atoms of Cl to one of Hg.

When the valences are different and neither is a mul of the other. Having the valence of each of the combi parts in mind, multiply each valence by some nu that will make the products equal. The number used will represent the number of atoms or parts to be taken.

*Example:*

$$As+O=As_2O_3$$

Here the valence of As is 3, O is 2.

As$-3\times2=6$
O $-2\times3=6$
No. of atoms As is 2
No. of atoms O is 3

Therefore the combination is $As_2O_3$.

*Examples:*

$2Sb+3O=Sb_2O_3$ using the valence of Sb as 3
$2Sb+5O=Sb_2O_5$ using the valence of Sb as 5
$2Fe+3O=Fe_2O_3$ Valence of Fe$=3$
$3Ca+2(PO_4)=Ca_3(PO_4)_2$ Valence of Ca$=2$ of $PO_4=3$

Here 3 atoms of Ca satisfy 2 atoms of $PO_4$.

## SUMMARY OF VALENCES

CASE 1.—When valences of the combining substances are the same, a simple exchange of radicals completes the form for the new symbols, showing the reaction that has taken place.

*Example:*

$$BaCl_2+H_2SO_4=BaSO_4+2HCl.$$

Here the radicals $SO_4$ and Cl have changed places. There being 2 H's and 2Cl's, we have 2HCl.

CASE 2.—When one substance is univalent and the other has a valence of one, two, three, or four, the substance or element with the higher valence will take as many of the univalent atoms as there are units in t higher valence.

*Example:*

$$BaCl_2+2HNO_3=Ba(NO_3)_2+2HCl.$$

Here the high valence Ba=2, low valence Cl=1, u valent. Therefore it takes 2Cl's to satisfy Ba. In t reaction the Ba combines with $NO_3$. The valence $NO_3$ is univalent, therefore it will take two $NO_3$'s complete the symbol for Barium Nitrate, $Ba(NO_3)_2$.

CASE 3.—When the valences are different and neither univalent, take as many atoms of each element or radi as will make the product of the valence times the numb of atoms the same.

*Example:*

$$3ZnSO_4+2H_3PO_4=Zn_3(PO_4)_2+3H_2SO_4$$

Here the Zn and the H are to change places; the will unite with the $PO_4$, forming $Zn_3(PO_4)_2$ and the will unite with the $SO_4$ and form sulfuric acid, but is bivalent and $PO_4$ is trivalent. In order to unite th we must take 3 atoms of Zn and 2 parts of $PO_4$, as follow

$$\overset{2}{Zn}_3+\overset{3}{(PO_4)}_2=Zn_3(PO_4)_2$$

$$(Zn,\ valence\ (2)\times 3\ atoms)=(PO_4,\ valence\ (3)\times 2\ part$$
$$6=6$$

We obtain the $Zn_3$ by taking 3 parts of $ZnSO_4$.

We obtain the $(PO_4)_2$ by taking 2 parts of $H_3PO_4$.

This gives us also three parts of $SO_4$ to unite with parts of H, as shown above. This equals $3H_2SO_4$.

## EXAMPLES OF APPLIED VALENCE

| | |
|---|---|
| $H+Cl=HCl$ | Univalent |
| $Ba+SO_4=BaSO_4$ | Bivalent |
| $Ba+(OH)_2=Ba(OH)_2$ | Bivalent and univalent |
| $H_2+SO_4=H_2SO_4$ | Univalent and Bivalent |
| $Fe+Cl_3=FeCl_3$ | Trivalent and Univalent |
| $Fe_2+O_3=Fe_2O_3$ | Trivalent and Bivalent |
| $Ca_3+(PO_4)_2=Ca_3(PO_4)_2$ | Bivalent and Trivalent |

These examples cover nearly all cases to be met with in ordinary reactions.

## TABLE OF VALENCES

### Univalent

One atom equivalent to one H atom

| Elements. | | Radicals. | |
|---|---|---|---|
| *Symbols.* | *Names.* | *Symbols.* | *Names.* |
| Non-metals: | | Acids: | |
| Cl. | Chlorine | $NO_3$ | Nitrate |
| Br. | Bromine | $C_2H_3O_2$ | Acetate |
| F. | Fluorine | $MnO_4$ | Manganate |
| I. | Iodine | CN | Cyanide |
| Metals: | | $ClO_3$ | Chlorate |
| Na | Sodium | Hydrate: | |
| K. | Potassium | OH | Hydrate |
| Ag | Silver | | |
| $NH_4$ | Ammonium | | |
| H. | Hydrogen | | |

### BIVALENT

One atom equivalent to two H atoms

| ELEMENTS | | RADICALS | |
|---|---|---|---|
| *Symbols* | *Names.* | *Symbols.* | *Names* |
| Non-metals: | | Acid | |
| O . . . . | Oxygen | $SO_4$ . . . . . . | Sulfate |
| Metals: | | $CO_3$. . . . . . . | Carbonate |
| Ba . . . . . . | Barium | $C_2O_4$. . . . . . . | Oxalate |
| Ca . . . . . . . | Calcium | $CrO_4$ . . . . . | Chromate |
| Mg. . . . . . . . . | Magnesium | | |
| Sr. . . . . . . . . . . | Strontium | | |
| Zn. . . . . . . . | Zinc | | |
| Cd . . . . . . . . . | Cadmium | | |

### TRIVALENT

One atom equivalent to three H atoms

| ELEMENTS. | | RADICALS. | |
|---|---|---|---|
| *Symbols.* | *Names.* | *Symbols.* | *Names.* |
| Metals: | | | |
| Al. . . . . . | Aluminum | | |
| Au . . . . . . . . . . | Gold | Acid: | |
| Ra. . . . . . . . | Radium | $PO_4$. . . . . . . . . | Phosphate |

### QUADRIVALENT

One atom equivalent to four H atoms

| ELEMENTS. | |
|---|---|
| *Symbols.* | *Names* |
| Non-metal: | |
| Si ..... ....... | Silicon |
| Metal: | |
| Zr... ............ | Zirconium |

### HEXAVALENT

One atom is equivalent to six H atoms

| ELEMENTS. | |
|---|---|
| *Symbols.* | *Names.* |
| Metal: | |
| W...... ......... | Tungsten |

### VALENCE 1 AND 2

One atom equivalent to one and two H atoms

| ELEMENTS. | |
|---|---|
| *Symbols.* | *Names.* |
| Metals: | |
| Cu............... | Copper |
| Hg............... | Mercury |

### VALENCE 2 AND 3

One atom equivalent to two and four H atoms

| ELEMENTS. | |
|---|---|
| *Symbols.* | *Names* |
| Metals. | |
| Ni.. .. .. .. .. | Nickel |
| Co . ... . ...... | Cobalt |
| Fe ....... .. ... | Iron |
| Cr... .. ... .. . | Chromium |

### VALENCE 3 AND 4

One atom equivalent to three and four H atoms

| ELEMENTS. | |
|---|---|
| *Symbols* | *Names.* |
| Metals: | |
| Ir ...... ...... | Iridium |
| Ti........ ....... | Titanium |
| Mo............... | Molybdenum |

### VALENCE 2 AND 4

One atom equivalent to two and four H atoms

| ELEMENTS. | |
|---|---|
| *Symbols.* | *Names.* |
| Metals: | |
| Pb . . . . . . . . . . . . . | Lead |
| Sn . . . . . . . . . . . . | Tin |
| Mn . . . . . . . | Manganese |
| Pt . . . . . . . . . . | Platinum |
| Non-metals: | |
| C. . . . . . . . . . . . . . . . | Carbon |
| S. . . . . . . . . . . . . . . . | Sulfur |

### VALENCE 3 AND 5

One atom equivalent to three and five atoms

| ELEMENTS. | |
|---|---|
| *Symbols.* | *Names.* |
| Metals: | |
| Bi . . . . . . . . . . . . . | Bismuth |
| Sb. . . . . . . . . . . . . . . | Antimony |
| As . . . . . . . . . . . . . . | Arsenic |
| Va . . . . . . . . . | Vanadium |
| Non-metals: | |
| P . . . . . . . . . . | Phosphorus |
| N. . . . . . . . . . . . | Nitrogen |

## TABLE OF ELEMENTS WITH NAMES OF SYMBOLS, VALENCE AND ATOMIC WEIGHTS.

| NAMES. | SYMBOLS | VALENCE | ATOMIC WEIGHTS. |
|---|---|---|---|
| Aluminum | Al | 1 | 27 |
| Antimony | Sb | 3 and 5 | 120 |
| Arsenic | As | 3 and 5 | 75 |
| Barium | Ba | 2 | 137 |
| Bismuth | Bi | 3 and 5 | 208 |
| Bromine | Br | 1 | 80 |
| Cadmium | Cd | 2 | 112 |
| Carbon | C | 2 and 4 | 12 |
| Chlorine | Cl | 1 | 35 5 |
| Chromium | Cr | 2 and 3 | 52 |
| Cobalt | Co | 2 and 3 | 59 |
| Copper | Cu | 1 and 2 | 64 |
| Fluorine | F | 1 | 19 |
| Gold | Au | 3 | 197 |
| Hydrogen | H | 1 | 1 |
| Iodine | I | 1 | 127 |
| Iridium | Ir | 2 and 4 | 193 |
| Iron | Fe | 2 and 3 | 56 |
| Lead | Pb | 2 and 4 | 207 |
| Magnesium | Mg | 2 | 24 |
| Manganese | Mn | 2 and 4 | 55 |
| Mercury | Hg | 1 and 2 | 200 |
| Molybdenum | Mo | 3 and 4 | 96 |
| Nickel | Ni | 2 and 3 | 58 5 |
| Nitrogen | N | 3 and 5 | 14 |
| Oxygen | O | 2 | 16 |
| Phosphorus | P | 3 and 5 | 31 |
| Platinum | Pt | 2 and 4 | 195 |
| Potassium | K | 1 | 39 |
| Radium | Ra | 3 | 226 |
| Rhodium | Rh | 2 and 4 | 103 |
| Silicon | Si | 4 | 28 |
| Silver | Ag | 1 | 108 |
| Sodium | Na | 1 | 23 |
| Strontium | Sr | 2 | 88 |
| Sulfur | S | 2 and 4 | 32 |
| Tin | Sn | 2 and 4 | 119 |
| Titanium | Ti | 3 and 4 | 48 |
| Tungsten | W | 6 | 184 |
| Vanadium | Va | 3 and 5 | 51 |
| Zinc | Zn | 2 | 65 |
| Zirconium | Zr | 4 | 91 |

## DEFINITIONS AND CHEMICAL TERMS

*Chemistry* is that branch of science that considers the properties of matter, its molecular structure and the chemical changes it undergoes.

*Matter* is anything that has weight and occupies space. It is made up of molecules, and molecules are composed of atoms. A **mass** is an aggregation of molecules large enough to be seen, while molecules are too small to be seen either by the naked eye or the microscope. The term mass is used to denote the quantity of matter in a body. A **molecule** is the smallest particle of matter into which a body can be divided and still retain its identity and which can exist in a free state. It is composed of atoms chemically combined. An **atom** is the smallest particle of matter that can enter into chemical combination.

*Properties of Matter.*—Matter is recognized and distinguished by its properties. To the familiar properties of taste, color, odor, weight, and solubility must be added the behavior with heat, light, and the effect of different kinds of matter upon each other.

*Chemical Change.*—In chemical changes the essential nature of the substance is affected, and the removal of the cause of the change does not restore the original properties. Physical and chemical changes usually accompany each other and often are inseparable.

*Acids.*—An acid is a body containing hydrogen, which hydrogen may be replaced by a metal or group of elements ($NH_4$) equivalent to a metal. As a class acids are sour. They are also chemical agents. Most acids are characterized by the property of changing the color of litmus, naturally a blue color, to red.

An acid symbol has two distinct parts, namely, the hydrogen and a group of non-metallic elements called an acid radical. If this radical contains oxygen, and the amount of oxygen varies, the acid name terminates in *ic* and the acid with the smaller amount of oxygen terminates in *ous*. The acids terminating in *ic* are usually the more stable acids.

When an acid gives up its hydrogen and takes a metal in its place, it becomes a **salt**. Salts from the *ous* acids terminate in *ite;* and salts formed from the *ic* acids terminate in *ate*. If the acid contains no oxygen it is a binary acid, and when it becomes a salt it is a binary salt and has the ending *id* or *ide*.

*Bases.*—A base is a compound usually an oxid or a hydrate, of a metal or group of elements equivalent to a metal. An **alkali** is a base of specially active character. It can easily be recognized by its solubility in water, to which it imparts a soapy taste and feeling, and also by its ability to restore the blue color to litmus which has been turned red by an acid.

Bases, as is said above, are oxids of metals or hydrates. An oxid, as its name indicates, is the product of the action of oxygen on a metal. A **hydrate** is composed of a metal and OH, called a hydrate radical. It is the same for all hydrates. The name **hydroxide** is often used meaning the same thing as a hydrate.

*Valence.*—The valence of an element or group of elements signifies its combining power with other elements as compared with the combining power of an atom of hydrogen.

## CHEMICAL LAWS

*The Indestructibility of Matter.*—The weight of resulting compounds is invariably the same and is equal to the sum of the weights of the substances entering into the reaction.

*The Law of Definite Proportion.*—The proportions by weight, according to which elements combine, are invariably the same for the same compound.

*The Law of Multiple Proportions.*—When two elements combine to form more than one compound, the different weights of the one element that unite with the same weight of the other element bear a simple ratio to each other.

*Faraday's Law.*—When the same quantity of electricity acts upon different electrolytes, the ratio between the quantity of liberated products is the same as between their chemical equivalents.

*Law of Specific Heats.*—The product of the specific heat and the atomic weight of the solid elements is a constant quantity.

*Laws of Precipitation.*—(*a*) When, on mixing two substances in a solution, a new compound can be formed that is insoluble in the solvent employed, such compound will be formed and will appear as a precipitate. (*b*) When on mixing different substances a new substance that is volatile can be produced by a rearrangement of the atoms of the partaking substances, such new substances will be produced and will appear as a gas.

*Boyle's Law.*—The temperature remaining the same, the quantity of gas varies inversely as the pressure. As a necessary consequence of Boyle's Law, it may be stated that the density of a gas varies directly as the pressure and inversely as the volume; that is, the density increases as the pressure increases and decreases as the volur increases.

*Avogadro's Law.*—Equal volumes of all substance either elemental or compound, in a gaseous state, at t same temperature and pressure, contain the same numb of molecules.

*Gay-Lussac's Law.*—If the pressure remains constan every increase of 1°, Centigrade, in temperature produce in a given quantity of a gas, an expansion of 1/273 its volume at zero. The ratio in which gases combi is always a simple one, the volume of the resulting gaseo product bears a simple ratio to the volume of its co stituents.

*Law of Diffusion of Gases.*—The rate of the diffusic of two gases is inversely as the square root of the densities.

*Henry's Law.*—The volume of a moderately soluble ga which is dissolved in water, is directly proportional t the pressure, if the temperature is constant.

*Periodic Law.*—The properties of the elements are periodic functions of their atomic weights.

## CHEMICAL TERMS

*An Anhydride* is a compound seeming to have a grea affinity for water, and in combining with water usuall forms an acid; as phosphoric anhydride, $P_2O_3$; carboni acid, $CO_2$, and sulfurous anhydride, $SO_2$.

*Dehydrate* means to take away its supposed molecule water of combination changing the crystalline form of th compound to an amorphous powder, as $CuSO_45H_2O$, blue crystal, when heated becomes a light blue powder an is said to be dehydrated.

*Catalysis* is a chemical process in which a reagent i employed to assist in the separation or union of two other elements or compounds, but itself remains unchanged.

Illust. $KClO_3+MnO_2+\text{heat}=KCl+MnO_2+3O$
NOTE: The catalyzing agent here is $MnO_2$.

*An allotropic substance* is one in which the substance assumes different properties under different conditions, as in the case of sulfur.

*Isomeric.*—The term isomeric is applied to substances having the same composition but different properties.

*Crystalline substances* are those in which the molecules are arranged in accordance with some geometrical design or system, while an amorphous substance has no such arrangement.

*Amorphous substances* have no crystalline arrangement of their molecules.

*Density* is the term used to denote the comparative $\left\{\begin{matrix}\text{weight}\\ \text{mass}\end{matrix}\right\}$ of a substance, of equal volume with that used as a standard.

The density of *solids* and *liquids* is usually compared with that of water as a standard. Hydrogen is used as a standard for determining the density of gases. *Air* is also used as a standard in measuring the density of some gases. *Density* and *specific gravity* signify the same thing.

*Deliquesce.*—Substances that take water from the air and in so doing appear to melt are said to deliquesce. Such substances are said to be hygroscopic and dissolve in the absorbed water, while others do not.

*Efflorescence.*—By efflorescence is meant the gradual crumbling of a substance, usually crystalline, to a powder, due to the escape of water of crystallization on exposure to the air or to the presence of heat.

*Effervesce.*—A substance effervesces when bubbles of gas seem to generate in the substance. Effervescing s stances are usually in a liquid state or semi-liquid cor tion.

*Chemism* is that attractive force existing between ato and molecules for each other that holds them in chemi combination. It is also called chemical affinity, a varies in intensity with the molecular structure of ı substance.

*A reagent* is any substance employed to cause a reacti It may be an acid, salt, or a base, and usually enters ir combination with the substance on which it acts.

*A reaction* is the chemical change that takes pl between the reagent and the substance acted upon.

*Nascent State.*—A substance is said to be in a nasce state when it has just been set free from chemical combir tion, and is ready to unite with those elements for whi it has a greater affinity.

*Oxidation* is the process of the union of oxygen wi other elements.

*Reduction* is the process of extracting oxygen from su stances containing it by other substances with which combines more readily.

*An oxidizing agent* is one that readily gives up its oxyg to another substance.

*A reducing agent* is one that takes oxygen from anoth substance.

*Metathesis,* or double decomposition, takes place wh two compounds are decomposed and the metallic elemer exchange places, as when a solution of $AgNO_3$ is mix with a solution of $NaCl$, forming $AgCl$ and $NaNO_3$.

*Hydrolysis* takes place when one of the products of double decomposition is $H_2O$.

*Synthesis* means the union of two or more elemen into a single compound.

## COMPOSITION, PROPERTIES AND CONSTRUCTION OF ACIDS, BASES AND SALTS

Much success in the study of elementary chemistry lies in the clear understanding of the names of the parts that enter into the forming of the several classes of chemical compounds and the particular chemical property their presence introduces.

Chemical compounds are distinguished and classified according to their properties and composition, for example:

| *As to properties* | *As to composition* |
|---|---|
| Acids are sour. | Acids have H and an acid radical |
| Hydrates are soapy. | Hydrates have a metal and a hydrate radical. |
| Salts are salty. | Salts have a metal and an acid radical |
| Oxides are neutral. | Oxides have an element and oxygen. |

The separation of an acid symbol into H and an acid radical is the key to the formation of the symbols of all the salts. All acids have H. If we take away the H from the symbol of each of the acids what we have left is called the acid radical, to which if we prefix the symbol for any metal using the proper combining valence, we have the symbol for the salt of that metal. Each acid has its own acid radical: for example, sulfuric acid, $H_2SO_4$, has $SO_4$ for its acid radical; $HNO_3$, nitric acid, has $NO_3$, radical; HCl, hydrochloric acid has Cl for its radical, and so on. Now, if to these radicals we add any of the metal elements we form the compounds called salts; as

$Cu+SO_4=CusO_4$, Copper Sulfate,
$Cu+Cl_2=CuCl_2$, Copper Chlorid;

and so we may take each acid in turn, noticing its composition, take away its H, leaving the radical of that acid which may combine with the metal symbols to produce salts of those metals. This will be shown more fully in the following table:

| *Acid Name.* | *Ending.* | *Symbol.* | *Composition.* | *Salt Composition* | *Salt Name.* |
|---|---|---|---|---|---|
| Hydrochloric............ ... | ic | $HCl$ | $H + Cl$ | Metals+$Cl$ | Chlorids |
| Sulfuric..... ............... | ic | $H_2SO_4$ | $H_2 + SO_4$ | Metals+$SO_4$ | Sulfates |
| Nitric................ ..... | ic | $HNO_3$ | $H + NO_3$ | Metals+$NO_3$ | Nitrates |
| Acetic...................... | ic | $HC_2H_3O_2$ | $H + C_2H_3O_2$ | Metals+$C_2H_3O_2$ | Acetates |
| Carbonic............. .. .. | ic | $H_2CO_3$ | $H_2 + CO_3$ | Metals+$CO_3$ | Carbonates |
| Phosphoric........... ..... | ic | $H_3PO_4$ | $H_3 + PO_4$ | Metals+$PO_4$ | Phosphates |
| Hydriodic ............... | ic | $HI$ | $H + I$ | Metals+$I$ | Iodids |
| Hydriobromic........... . | ic | $HBr$ | $H + Br$ | Metals+$Br$ | Bromids |
| Chromic...... ............ | ic | $H_2CrO_4$ | $H_2 + CrO_4$ | Metals+$CrO_4$ | Chromates |
| Chloric..................... | ic | $HClO_3$ | $H + ClO_3$ | Metals+$ClO_3$ | Chlorates |

Notes.—Salts formed from acids of only 2 elements end in id or are "ids."

Salts formed from acids of only 3 elements ending in ic are "ates."

Salts formed from acids of only 3 elements ending in ous are "ites."

## CLASSES OF SALTS

Classes of salts are named by the use of certain endings or prefixes that are given them showing from what acid they are derived.

Salts ending in "ate" are derived from acids ending in "ic."

Salts ending in "ite" are derived from acids ending in "ous."

Salts ending in "id" are derived from acids having only two elements, like HCl.

Salts with the prefix "hyper" mean that the acid from which they are formed was in an unsaturated condition.

Salts with the prefix "per" mean that they, on the other hand, are derived from acids supersaturated.

Supersaturated and hyper or undersaturated are both unstable conditions of acids.

NOTE —Salts may be *Normal*, *Basic* or *Acid*. A normal salt is sometimes called a neutral salt Normal salts contain no H Acid salts contain H. Basic salts contain O in combination with the metal of the salt.

NORMAL SALTS

| | |
|---|---|
| Potassium Sulfate | $K_2SO_4$ |
| Sodium Sulfate | $Na_2SO_4$ |
| Sodium Carbonate | $Na_2CO_3$ |

BASIC SALTS

| | |
|---|---|
| Basic Chlorid of Bismuth | BiOCl |
| Basic Chlorid of Antimony | SbOCl |

ACID SALTS

| | |
|---|---|
| Potassium Acid Sulfate | $HKSO_4$ |
| Sodium Acid Sulfate | $HNaSO_4$ |
| Potassium Acid Carbonate | $HKCO_3$ |
| Sodium Acid Carbonate | $HNaCO_3$ |

The following list will show the application of the most common of these endings:

### SYMBOLS AND NAMES OF SALTS AS SHOWN BY TH ENDINGS AND THE ACID FROM WHICH THEY DERIVED

$$\text{Salts}\left\{\begin{array}{l}\text{ate's}\\ \text{ite's}\\ \text{id's}\end{array}\right\}\text{from}\left\{\begin{array}{l}\text{ic}\\ \text{ous}\\ \text{2 elements}\end{array}\right\}\text{acid endings.}$$

| SALTS | ACID RADICAL, Name | ENDING | ACID. |
|---|---|---|---|
| Metals and acid radical in "ate" | Sulfates | ate | Sulfuric |
| | Nitrates | ate | Nitric |
| | Chlorates | ate | Chloric |
| | Phosphates | ate | Phospho |
| | Carbonates | ate | Carbonic |
| Metals and acid radical in "ite" | Sulfites | ite | Sulfurou |
| | Nitrites | ite | Nitrous |
| | Chlorites | ite | Chlorous |
| | Phosphites | ite | Phospho |
| Metals and acid radical in "id" | Sulfids | ide | $H_2S$ |
| | Chlorids | ide | HCl |
| | Iodids | ide | HI |
| | Bromids | ide | HBr |

Metals + sulfate-radicals = Sulfate salts
Metals + nitrate-radicals = Nitrate salts
Metals + carbonate-radicals = Carbonate salts
Metals + sulfite-radicals = Sulfite salts
Metals + nitrite-radicals = Nitrite salts

## HYDRATES AND BASES

In the same way we may consider hydrates (hydroxid All hydrates have the same radical, OH, called hydro or hydrate radical. If a metal is prefixed to this radi a hydrate is formed. Considering the valence of OH univalent, its union with metals is illustrated as follow

| METAL | | RADICAL OH | | HYDRATE | |
|---|---|---|---|---|---|
| Ca | + | Radical $(OH)_2$ | = | $Ca(OH)_2$ | Calcium Hydrate |
| Na | + | Radical OH | = | NaOH | Sodium Hydrate |

If H is added to the hydrate radical, OH, instead of a hydrate, we have $H_2O$, or water. If an acid is added to a hydrate the H of the acid combines with the H of the OH and forms water, while the metal of the hydrate unites with the acid radical and forms a salt.

$$H_2SO_4+2KOH=K_2SO4+2H_2O$$

This will be more fully discussed under the heading Equations.

The more common hydrates with the symbols showing their structure and composition are given in the following table:

| OXIDS. | SYMBOLS. | NAMES | HYDRATES (Hydroxides) Symbols. |
|---|---|---|---|
| Barium oxid | BaO | Potassium hydrate | KOH |
| Calcium oxid | CaO | Ammonium hydrate | $NH_4OH$ |
| Zinc oxid | ZnO | Sodium hydrate | NaOH |
| Magnesium oxid | MgO | Calcium hydrate | $Ca(OH)_2$ |
| Manganese oxid | MnO | Barium hydrate | $Ba(OH)_2$ |
| Ferric oxid | $Fe_2O_3$ | Magnesium hydrate | $Mg(OH)_2$ |
| Copper oxid | CuO | Ferric hydrate | $Fe_2(OH)_3$ |
| Lead oxid, etc | PbO | Zinc hydrate | $Zn(OH)_2$ |
| Metal+oxygen | | Aluminium hydrate | $Al(OH)_3$ |

NOTE —Valence of oxygen is 2 Metal+radical (OH)=hydrate

Potassium hydrate
Sodium hydrate
Ammonium hydrate
} are called alkalies

**The chemical effect of acids, bases and salts upon e other.**

An acid will neutralize or destroy the properties o hydrate, and, on the other hand, a hydrate will do same to an acid; and as was said before, the effect of reaction between an acid and a base is to produce a and water.

### ACIDS MOST FREQUENTLY USED IN QUALITATIVE A QUANTITATIVE INORGANIC ANALYSIS AND T CLASSES OF SALTS DERIVED THEREFROM

| NAME. | SYMBOL | CLASS OF SA |
|---|---|---|
| Sulfuric acid . . . . . . | $H_2SO_4$ | Sulfates |
| Nitric acid. . . . . . . . . . | $HNO_3$ | Nitrates |
| Hydrochloric acid . . . . | $HCl$ | Chlorides |
| Acetic acid . . . . . . . | $HC_2H_3O_2$ | Acetates |
| Phosphoric acid. . . . . . . . . | $H_3PO_4$ | Phosphates |
| Oxalic acid . . . . . . . . . . . . . | $C_2H_2O_4$ | Oxalates |
| Carbonic acid . . . . . . . | $H_2CO_3$ | Carbonates |
| Hydriodic acid. . . . . . . . . | $HI$ | Iodids |
| Hydriobromic acid . . . . | $HBr$ | Bromids |
| Hydrofluoric. . . . . . . . . . . . . | $HF$ | Fluorids |
| Sulfurous acid. . . . . . . . . . | $H_2SO_3$ | Sulfites |
| Hydrocyanic acid. . . . | $HCN$ | Cyanides |

### HYDRATES MOST FREQUENTLY USED.

| NAME. | SYMBOL. | PROPERTY. |
|---|---|---|
| Aqua ammonia . . . . . . | $NH_4OH$ | Strongly alka |
| Potassium hydrate . . . | $KOH$ | Strongly alka |
| Sodium hydrate . . . . . | $NaOH$ | Strongly alka |
| Calcium hydrate | $Ca(OH)_2$ | Weakly alkal |
| Barium hydrate | $Ba(OH)_2$ | Weakly alkal |

## CHEMICAL EQUATIONS

Whenever a chemical reaction takes place between two substances, a statement of the substances acting and the results of the reaction is shown in the form of an **equation.**

For example:

$$ZnO+H_2SO_4=ZnSO_4+H_2O$$

This equation states that zinc oxid and sulfuric acid brought together produced zinc sulfate and water. Furthermore, if a definite amount of zinc oxid be taken it will combine only with a definite amount of sulfuric acid and would produce a definite amount of $ZnSO_4$ and $H_2O$.

## CLASSES OF EQUATIONS

There are five classes of equations in common use, corresponding to five types of reactions.

1st. The union of metals and O producing oxids:

$$Cu+O=CuO.$$

2d. Oxids and acids producing salts and water:

$$CuO+H_2SO_4=H_2O+CuSO_4.$$

3d. Hydrates and acids producing salts and water:

$$Cu(OH)_2+H_2SO_4=CuSO_4+2H_2O.$$

4th. Salts and acids producing other salts and other acids:

$$CuSO_4+2HCl=CuCl_2+H_2SO_4.$$

5th. Salts and salts producing other salts:

$$Pb(C_2H_3O_2)_2+Na_2CO_3=PbCO_3+2NaC_2H_3O_2.$$

In considering those different classes we see that wherever a reaction takes place it results in simply a change of the parts that compose the molecules brought about by a greater molecular or atomic affinity existing between them when in solution, the metal changing with the hydrogen of the acid, or the metals of another salt, thereby forming new compounds.

To illustrate again take the equation,

$$Zn(OH)_2+H_2SO_4=ZnSO_4+2H_2O.$$

In the first place the Zn of the Zn hydrate $Zn(OH)_2$ unites with the $SO_4$ of the $H_2SO_4$ displacing the $H_2$, thereby forming the salt $ZnSO_4$: the Zn is bivalent so it will displace the 2 H's of the acid, and will unite with the $SO_4$ which is also bivalent, forming a compound which has its two parts each bivalent. The $H_2$ set free unites with the $(OH)_2$, forming a compound with 4 H's and 2 O's, which unite to form $2H_2O$, or two parts of water.

NOTE.—The number before the symbol means that each atom in the compound is to be taken as many times as the number indicates, and the number below shows that the atom alone is to be affected by it.

Considering the equation:

$$CuSO_4+2HCl=CuCl_2+H_2SO_4.$$

When a bivalent element or radical unites with a bivalent it takes only one part of each, and when a bivalent unites with a univalent of course it takes two univalent elements to satisfy one bivalent particle, and likewise one univalent unites with one univalent particle and so on, so that in the above equation, when the Cu of the $CuSO_4$ unites with Cl of the HCl, the Cu being bivalent requires two Cl's, as Cl is univalent. Now, in order to obtain the necessary amount of Cl to unite with the Cu we will have to double the amount of HCl and write it as it is in the equation 2HCl, thus giving the right amount of Cl to combine with the Cu to form $CuCl_2$, the correct symbol for $CuCl_2$, Copper Chlorid.

Again, the $SO_4$ being bivalent, requires two H's to form the acid, by taking twice the amount of HCl above we have the required amount of H for the sulfuric acid, $H_2SO_4$, and our equation is properly completed. This is what is called balancing the equation.

In the equation $CuO+H_2SO_4=CuSO_4+H_2O$, when the copper changes place with the $H_2$, nothing has to be changed, because the two H's are equivalent to the Cu, so that the Cu simply takes the place of the $H_2$, and the $H_2$ unites with the O left by the Cu and forms $H_2O$.

Again in the equation:

$$Co(NO_3)_2+2KCN=2KNO_3+Co(CN)_2.$$

Here the Co and the K change places, the Co bivalent and the K univalent, so that one Co is equal to two K's, in the equation we have only one K, so we must take twice the amount of KCN to satisfy the Co, and balancing the equation to accomplish this we have 2KCN, and the equation becomes $Co(NO_3)_2+2KCN=2KNO_3+Co(CN)_2$. The $NO_3$ (nitrate radical) is univalent, and so the $(NO_3)_2$ will satisfy the Co which is bivalent.

Likewise, the equation:

$$K_2O+H_3PO_4=K_3PO_4+H_2O$$

In this case, $PO_4$ is trivalent, and takes three H's or $H_3$, but the $K_2$ cannot displace $H_3$ because the result would be only a partial displacement. However, by taking proper amounts of each substance a complete reaction may take place. If then we take three parts of $K_2O$ to two parts of $H_3PO_4$, the atoms and radicals will

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change places in their proper combining proporti that is, $3K_2O$ will combine with $2H_3PO_4$, and this balance the equation, and we have:

$$3K_2O+2H_3PO_4=2K_3PO_4+3H_2O.$$

## Practice Work for the Study of Writing and Balan Equations

1. The formation of the oxids of the metals.
2. Combining the oxids with acids.
3. Combining hydrates with acids.
4. Combining salts with acids.
5. Combining salts with hydrates.
6. Combining salts with salts.

### Oxids

The symbol for oxids with metals with a valence of (univalent), as Na, will be:

$$Na_2O$$

For oxids of metals with a valence of two (bivalent) Ba, the symbol will be:

$$BaO$$

For oxids of metals with a valence of three (trival as As, the symbol will be:

$$As_2O_3$$

For oxids of metals with a valence of four (quadrivale as Mn, the symbol will be:

$$MnO_2$$

For oxids of metals with a valence of five (penta as Sb, the symbol will be:

$$Sb_2O_5$$

For oxids with a valence of six (hexads), as W, the symbol will be:

$$WO_3$$

Complete the following sets of equations:

### METALS AND OXYGEN = OXIDS

$Ag+O=$
$K+O=$
$Na+O=$
$Pb+O=$
$Cu+O=$
$Ca+O=$
$Ba+O=$
$Sn+O=$
$Sn+O=$
$Fe+O=$
$Fe+O=$
$Ni+O=$
$Ni+O=$

$Cr+O=$
$Cr+O=$
$As+O=$
$As+O=$
$Bi+O=$
$Bi+O=$
$Sb+O=$
$Sb+O=$
$Cd+O=$
$Hg+O=$
$Hg+O=$
$Zn+O=$
$Co+O=$

### Oxids and Acids = Salts and Water

Complete each equation, combining the oxids as given below with each acid in the given list of acids.

OXIDS

$K_2O$ + each acid =
$Ag_2O$ + each acid =
$Na_2O$ + each acid =
$PbO$ + each acid =
$PbO_2$ + each acid =
$Cu_2O$ + each acid =
$CuO$ + each acid =
$CaO$ + each acid =
$BaO$ + each acid =

OXIDS

$SnO$ + each acid =
$SnO_2$ + each acid =
$FeO$ + each acid =
$Fe_2O_3$ + each acid =
$CrO$ + each acid =
$Cr_2O_3$ + each acid =
$As_2O_3$ + each acid =
$As_2O_5$ + each acid =
$Sb_2O_3$ + each acid =
$Sb_2O_5$ + each acid =

ACIDS

$H_2SO_4$
$HNO_3$

$HCl$
$HC_2H_3O_2$

$H_2CO_3$
$H_3PO_4$

### Acids+Hydrates = Salts+Water

NOTE.—Acids = H+acid radical
Hydrates = Metal+OH (hydrate radical) univalent.

Complete each equation combining the hydrates of t list with each of the following:

ACIDS

$H_2SO_4$
$HNO_3$
$HCl$
$HC_2H_3O_2$
$H_2CO_3$
$H_3PO_4$

$NaOH$ +acid =
$KOH$ +acid =
$Ca(OH)_2$ +acid =
$NH_4OH$ +acid =
$Ba(OH)_2$ +acid =
$Al(OH)_3$ +acid =
$AgOH$ +acid =
$HgOH$ +acid =
$Hg(OH)_2$ +acid =
$Fe(OH)_2$ +acid =

$CuOH$ +acid =
$Cu(OH)_2$ +acid =
$Bi(OH)_3$ +acid =
$Bi(OH)_5$ +acid =
$Sb(OH)_3$ +acid =
$Sb(OH)_5$ +acid =
$Sn(OH)_2$ +acid =
$Sn(OH)_4$ +acid =
$Cr(OH)_2$ +acid =
$Cr(OH)_3$ +acid =
$Fe(OH)_3$ +acid =

### Hydrates and Salts = New Hydrates and Salts

Combine the following list of hydrates and salts.

| HYDRATES | | SALTS | |
|---|---|---|---|
| $NH_4OH$ | + | $AgNO_3$ | = |
| $KOH$ | + | $PbCl_2$ | = |
| $NaOH$ | + | $CuSO_4$ | = |
| $Ca(OH)_2$ | + | $AlCl_3$ | = |
| $NH_4OH$ | + | $FeCl_3$ | = |
| $NH_4OH$ | + | $BaSO_4$ | = |
| $NaOH$ | + | $NH_4Cl$ | = |
| $Ba(OH)_2$ | + | $CuSO_4$ | = |
| $NH_4OH$ | + | $NaCl$ | = |

Combine the following lists of salts.

| Salts | | Salts | |
|---|---|---|---|
| $Pb(C_2H_3O_2)_2$ | + | $NH_4OH$ | = |
| $Pb(C_2H_3O_2)_2$ | + | $Na_2CO_3$ | = |
| $BiCl_3$ | + | $(NH_4)_2S$ | = |
| $Sb_2S_3$ | + | $(NH_4)\ S$ | = |

## Miscellaneous Equations

Show that the following equations are correct.

1. $K_2Cr_2O_7+4H_2SO_4=K_2SO_4+Cr_2(SO_4)_3+4H_2O+3O$.
2. $NH_4Cl+KNO_2=NH_4NO_2+KCl$.
3. $NH_4NO_2=+2H_2O+N_2$.
4. $NH_3+3Cl=N+3HCl$.
5. $NH_3+HCl=NH_4Cl$.
6. $H_2SO_4=SO_2+O+H_2O$.
7. $2H_2SO_4+S=3SO_2+2H_2O$.
8. $2H_2SO_4+C=2SO_2+2H_2O+CO_2$.
9. $2H_2SO_4+Cu=SO_2+2H_2O+CuSO_4$.
10. $Al(OH)_3+3KOH=K_3AlO_3+3H_2O$.
11. $AlCl_3+3H_2O=3HCl+Al(OH)_3$.
12. $HgCl_2+2KOH=HgO+2KCl+H_2O$.
13. $HgSO_4+2NaCl=Na_2SO_4+HgCl_2$.
14. $K_2CO_3+Ca(OH)_2=CaCO_3+2KOH$.
15. $NH_4HCO_3+NaCl=NaHCO_3+NH_4Cl$.

## MATHEMATICS OF CHEMISTRY

*Percentage of Composition.*—Knowing the molecular weight of any substance and the number of atoms it contains and the atomic weight of each constituent atom, the percentage composition (that is, the composition of 100 parts of the substance, the form in which analyses are usually expressed) can be easily found.

$M$ = Molecular weight
$a$ = Atomic weight
$N$ = Number of atoms in a constituent
$X$ = Percentage

Then,

$$X=\frac{100aN}{M}.$$

Example, calculation for percentage.

Sulfuric acid has a molecular weight of 98; its percentage composition is:

| | |
|---|---|
| Hydrogen ............... | 2.04 per cent |
| Sulfur.................... | 32.65 per cent |
| Oxygen ............... .. | 65.31 per cent |

Atomic weight of H = 1
Atomic weight of S = 32
Atomic weight of O = 16

Substituting these values in the above formula, we have:

$$X=\frac{100\times1\times2}{98}=2.04 \text{ per cent for H}$$

$$X=\frac{100\times32\times1}{98}=32\ 65 \text{ per cent for S}$$

$$X=\frac{100\times16\times4}{98}=65.31 \text{ per cent for O}$$

Formula for Sulfuric Acid = $H_2SO_4$.

### Calculations from Equations

The same arithmetical principles are applied in calculating the weights of substances that enter into or are producing chemical changes. The change should be expressed by an equation. The molecular weights of all the precipitating compounds are calculated from the table of atomic weights, and are placed below their formulas. All reactions must conform to the following rule:

*The molecular weight of a given substance is to the absolute weight of it, as the molecular weight of the required substance is to the required quantity.*

*Example.*—A certain chemical reaction is represented by the following equation:

$$\begin{array}{ccccccc} Zn(NO_3)_2 & + & K_2CO_3 & = & ZnCO_3 & + & 2KNO_3 \\ 189 & & 138 & & 125 & & 202 \end{array}$$

If 156 grams represents an amount of $Zn(NO_3)_2$ and it yields 103.17 grams of $ZnCO_3$, and the molecular weight of $ZnCO_3$ is 125, find the molecular weight of $Zn(NO_3)_2$.

*Solution.*—Substituting the values just given in the formula

$$M=\frac{W\times m}{w},$$

we have

$$M=\frac{156\times125}{103\ 17}=189 \text{ mol. wgt. of } Zn(NO_3)_2.$$

Knowing the *absolute weight* and the *molecular weight* of the given substance, and also the *molecular weight* of the required substance, find the *absolute weight* of th required substance.

$$w=\frac{Wm}{M}.$$

$M$ = mol. wgt. of given substance required;
$m$ = mol. wgt. required substance;
$W$ = absolute wgt. of given substance;
$w$ = absolute wgt. required substance.

*Example.*—How much $ZnSO_4$ can be produced by th action of $H_2SO_4$ upon $ZnCl_2$. $H_2SO_4$ absolute weigh being 2 lbs.

$$\begin{array}{ccccccc} H_2SO_4 & + & ZnCl_2 & = & ZnSO_4 & + & 2HCl \\ 98 & & 136 & & 161 & & 75 \end{array}$$

$$98 : 161 :: 2 \text{ ℔} : X$$

$$X=\frac{161\times 2}{98}=3\ 286 \text{ ℔ of } ZnSO_4.$$

## INDICATORS

An indicator, in chemistry, is used to show whethe substance (usually in solution) is alkaline or acid in properties. Sometimes the amount of acidity or alk linity is required. Four indicators are in most comm use.

*Litmus.*—Either as a paper or as a solution. Ac turns this indicator red. Hydrates or bases turn it bl

*Methyl-orange.*—Turns yellow in alkaline solutions a pink in acids, though it is unaffected by $CO_2$, carbo acid gas.

*Phenolphthalein.*—Is colorless in acid solutions b turns red in alkaline solutions, and is very sensitive to $CO_2$, in contrast to methyl-orange.

*Cochineal.*—Soluble in 25 per cent alcohol, a yellowish-red solution, turns violet with alkalies. The color is restored by acids.

## QUALITATIVE ANALYSIS

**Qualitative Analysis** is that part of the science ot chemistry that has to deal with the constituents of chemical compounds, their determination, and identification. Qualitative analysis does not attempt to answer the question "how much," but "what." A sample of a substance is submitted for analysis, with the request to know "what it contains." To find this out it is necessary to break up the compound into its parts, and then test the parts; salts, acids, or hydrates, to identify them, and thereby determine the composition of the compound. This is qualitative analysis. If the amount of each part that composes the compound is to be determined, that is done by a process called **quantitative analysis.**

*Preliminary Tests.*—The method of procedure for the analysis of an unknown sample should be definite and systematic. Whether it be a solution or a solid, the order of treatment should be followed that will *secure accuracy,* and that will *cut out unnecessary work* or *waste of material.* If the sample submitted is in **solution,** certain properties of color, taste, odor, viscosity, volatility, etc., may give the observant analyst a hint as to what it may contain. Divide the sample into parts, one part to be laid aside for tests on acid residues, the other part to be treated for basic residues, or for the kind of metal that may be in the compound. The test for the determination of what acid radical the met combined with, is called the test for the *acid re* The tests for *basic residues,* or the metallic groups to be studied first. When testing for the diff groups of metals, take first a small portion of the sol in a test-tube, and adding the group reagent, begi with the first group, determine whether any of the m of that group are present. If not, pass on to the till the group is found that contains the elements o compound. Then proceed with the analysis of the m of that group.

In the separation of the metals of any group a ca check must be taken on each filtrate carried forward t following group to make sure that all the metals o preceding groups have been precipitated, as any g reagent, not only precipitates the metals of its group, but those of all the preceding groups.

In every case where a precipitate is obtained it mu thoroughly washed (unless directed otherwise) with water, either by decantation or directly on the f This is to prevent any of the filtrate from rema in the pores of the precipitate, thereby seriously i fering with the analysis.

In the use of the *reagents, add carefully and sl* especially at first, watching for any change of or the formation of precipitates, as some redissol an excess of the reagent. It is necessary, howeve add enough to precipitate all of the metal contain the solution. If at any time there is any doubt, well to take a portion of the solution and run in mo the reagent and watch for further reaction.

Keep in mind, also, the important fact that *accelerates reaction,* both in solution and precipita If a precipitate does not settle upon the addition reagent, or if it gives only a cloudy appearance, heat the solution to determine whether a precipitation is possible.

*Preparation of Solid Samples for Analysis.*—There are two general methods for analysis of solid compounds, the **wet** and the **dry**. The wet method consists in dissolving the solid and bringing the material into solution, in which case the process of analysis is conducted by the ordinary or wet method. Some substances are not very easy to dissolve, and may receive a preliminary dry test, which consists in subjecting a portion of the sample to be tested to the influence of heat; if tested in the flame of a Bunsen burner, the color of the flame is noted which is very characteristic for some elements as Na, K, and Ca.

It may also be placed on a piece of *charcoal* and subjected to the **oxidizing** or the **reducing** flame of this same burner. The oxidizing flame is the outside portion of the burning gas, and oxidizes substances burned therein, while the inner cone, darker in appearance is called the reducing flame, because it takes oxygen away from the substance placed in it. This is because the gas is only partially consumed or oxidized, and therefore readily combines with the oxygen brought to it by any other substance. The effect of producing incrustations, of various colors and properties, identifies the material in many instances.

Another preliminary test consists in giving it the **borax bead test.** To carry out this test, a piece of platinum wire (about 2 inches long, No. 26 B. & S.) is taken, one end fastened into a small piece of glass tubing, and a small loop made at the other end. This is first dipped into HCl to clean it, then held in the Bunsen flame, and afterward dipped in borax powder and held in the flame again. The powder will melt and form a glassy bead called the "borax bead." When this is moistened in HCl and dipped in the substance to tested and held in the flame it will impart a characteris color, that often leads to its identification.

## Special Notes

*Solubility.*—All substances may be divided into th classes as to solubility: (*a*) Those that are soluble water. (*b*) Those insoluble in water but soluble acids. (*c*) Those substances decomposed by fusing wi carbonates.

Some substances may contain all three classes. In th case, heat a little of the substances in a test-tube in wat filter, test filtrate for compounds that may have gone ir solution, treat the undissolved part with acids. T excess of acids should be driven off with heat and t balance diluted with water, filtered, and the filtr tested for the substances that may have dissolved acids, and the residue, if any remains, fused with c bonates of sodium and potassium. By this treatm all compounds may be dissolved.

## Compounds Soluble in Water

(*a*) Chlorates, acetates, hypochlorites, formates.
Chlorids, bromids, iodids.
Nitrates, nitrites.
Sulfates.
Alkalies and their compounds.
Chromates of Cu, Zn, Mn, Fe, Hg(ic).
Oxalates of Cr, Al, Sb, Fe(ic), Sn(ic).
Sulfids of Ba, Ca, Sr, Mg.
Cyanids, arsenates, arsenites, acid carbona (partly).

Exceptions:

Chlorids, bromids, iodids, of Pb, Ag, Hg(ous).
A few basic nitrates.
Sulfate of Pb, Hg(ous), Ba, Sr, Ca.
Metantimonate of Na, potassium silico-fluorid, and complex silicates.
Sulfids of Ca, and Mg dissolve with difficulty.
$CaSO_4$ is partially soluble in a large amount of water.

## Compounds Insoluble in Water

(*a*) Place a portion in test-tube, add HCl (*c*), boil, if necessary. This process changes many substances to soluble chlorids, and water is formed, or the acid, if volatile, is driven off; if non-volatile, remains in solution.

(*b*) If this treatment fails, heat a small quantity in a test-tube with $HNO_3$ (*c*). This will oxidize some insoluble compounds forming soluble ones, as mercurous chlorid is oxidized to mercuric, etc.

(*c*) If the substance is not dissolved by either of these acids, separately, it should be boiled in *aqua regia*. In case the substance is dissolved by any one of the above acids, the excess acid is driven off by heat, and the remaining solution diluted with several times its bulk of water, and then tested in the way of ordinary solutions. In case of partial or doubtful solubility the excess acid should be driven off, water added, the substance filtered, and the clear filtrate tested to see if a part of the substance has been dissolved.

(*d*) If the substance will not dissolve in either water or any of the above acids, it must be fused with about six times its weight of $Na_2CO_3$ and $K_2CO_3$, equal parts.

Most substances dissolve in either water or one of above acids, but a few including anhydrous silicates, sulfates of barium, strontium, and possibly calci remain undissolved. The fusion is made in a platin crucible and must be continued until chemical act ceases, and the fusion becomes quiet. Substances t would alloy with platinum must not be treated in t manner.

The fusion after cooling is transferred to a small bea and boiled with water until it is thoroughly disintegrat The acid combined with an alkali will now be in solut and the carbonate or oxide of the metal will rem undissolved. Filter and test the filtrate for the a then dissolve in hydrochloric acid the residue t remains on the filter and test this solution for the me

Pulverized silicates that are insoluble in acids used r be decomposed by HF acid. This method must resorted to when the alkalies are to be determined.

## Reactions for the Basic Residues

Basic residues are those precipitates in which the b element of the reaction is considered.

Principal tests for the metals of the several groups

**Silver, Ag** $AgNO_3$, soluble in $H_2O$.

| | *Reagents* | | | *Reactions* | | |
|---|---|---|---|---|---|---|
| $2AgNO_3$ | + | $H_2S$ | = | $Ag_2S$<br>(b)<br>Insol. in $(NH_4)_2S$<br>Sol. in $NHO_3$ | + | $2HNO_3$ |
| $AgNO_3$ | + | HCl | = | AgCl<br>(w)<br>Sol. in $NH_4OH$<br>Repr. by $HNO_3$ | + | $HNO_3$ |

**Lead, Pb.** $Pb(C_2H_3O_2)_2$, sol. in $H_2O$

$Pb(C_2H_3O_2)_2 + H_2S = PbS + 2HC_2H_3O_2$
(b)
Insol. in $(NH_4)_2S$
Sol. in $HNO_3$

$Pb(C_2H_3O_2)_2 + 2HCl = PbCl_2 + 2HC_2H_3O_2$
(w)
Sol. in hot water

$Pb(C_2H_3O_2)_2 + H_2SO_4 = PbSO_4 + 2HC_2H_3O_2$
(w)
Sol. in acetic $+NH_4OH$
In excess + boil.

$Pb(C_2H_3O_2)_2 + Na_2CO_3 = PbCO_3 + 2NaC_2H_3O_2$
(w)

$Pb(C_2H_3O_2)_2 + K_2CrO_4 = PbCrO_4 + 2KC_2H_3O_2$

NOTE.—When using $Pb(NO_3)_2$, make ammoniacal before using HCl.

**Mercury, Hg (ous)** $HgNO_3$, sol in $H_2O$

$2HgNO_3 + H_2S = Hg_2S + 2HNO_3$
$Hg_2S$ separates into $HgS + Hg$

$2HgNO_3 + NH_4OH = 2NH_2Hg_2NO_3 + NH_4NO_3 + 2H_2O$ (Different from mercuric)

$HgNO_3 + KI = HgI + KNO_3$ (Different from mercuric)
(g)

$HgNO_3 + HCl = HgCl + HNO_3$ (Different from mercuric)
(w) HgCl is "Calomel"

**Copper, Cu.** $CuSO_4$, sol. in $H_2O$

$CuSO_4 + H_2S = CuS + H_2SO_4$ Sol. in $HNO_3$ (h), sol in (b) KCN, insol. in $H_2SO_4$ dilute

$CuSO_4 + 2NH_4HO = Cu(OH_2 + (NH_4)_2 SO_4$ Sol. in excess of reagent. Changes to deep blue —$Cu(NH_3)SO_4$. Color destroyed by KCN

$2CuSO_4 + K_4Fe(CN)_6 = Cu_2Fe(CN)_6 + 2K_2SO_4$. Insol. in acetic acid.
(br)

$CuSO_4+Na_2CO_3$ $=CuCO_3\ Cu(OH)_2$. Greenish-blue basic salt. Changes to black on boiling Equation:

$2Na_2CO_3+2CuSO_4+H_2O=2Na_2SO_4+CuCO_3,\ Cu(OH)_2+CO_2$.

### **Bismuth,** Bi $Bi(NO_3)_3$ sol. in HCl (dilute)

$BiCl_3+H_2O$ $=BiOCl+2HCl$-$BiOCl$ Sol in mineral acids
(w). Insol. in $HC_2H_3O_2$ (different from $SbOCl$)

$2BiOCl+3H_2S$ $=Bi_2S_3+2H_2O+2HCl$
(b)

$2BiCl_3+3(NH_4)_2S$ $=Bi_2S_3+6NH_4Cl$
(b)

### **Antimony,** Sb $Sb_2O_3$. Sol. in HCl (dilute)

$2SbCl_3+3H_2S$ $=Sb_2S_3+6HCl$
(O)

$Sb_2S_3+2(NH_4)_2S+4HCl=Sb_2S_5+4NH_4Cl+2H_2O$

$SbCl_3+H_2O$ $=SbOCl+2HCl$. $SbOCl$, not sol. in $H_2O$. Sol in HCl Sol. in $HC_2H_3O_2$ (Different from $BiOCl$)

$2SbOCl+3H_2S$ $=Sb_2S_3+2HCl+2H_2O$

### **Cadmium,** Cd $CdCl_2$, sol in $H_2O$

$CdCl_2+H_2S$ $=CdS+2HCl$ CdS, sol in $HNO_3$ (h)
CdS, sol in $H_2SO_4$ (h)
CdS, insol. in KCN
CdS, insol in $(NH_4)_2S$

$CdCl_2+Na_2CO_3$ $=CdCO_3+2NaCl$ precip. prevented by free $NH_3$
(w)

### **Arsenic,** As. $As_2O_3$ sol in HCl (dilute)

$2AsCl_3+3H_2S=As_2S_3+6HCl$. $As_2S_3$, sol. in $(NH_4)_2S$, reprec. by HCl
(y)

NOTES.—(*a*) Metallic arsenic deposit,—$As_2O_3+Na_2CO_3+KCN+$ heat, in tube.
(*b*) Charcoal test,—odor, deposit. Garlic, white coating, volatil.

### **Tin,** Sn (ous). $SnCl_2$, sol in $H_2O$

$SnCl_2+H_2S$ $=SnS+2HCl$ SnS, sol in $(NH_4)_2S$(h)
(br) $SnS+HCl=SnS_2$ yellow p.
$SnCl_2+2HgCl_2$ $=2HgCl+SnCl_4$
(w)

### **Tin,** Sn (ic). SnCl, sol. in $H_2O$

$SnCl_4+2H_2S$ $=SnS+4HCl$ $SnS_2$, sol in $(NH_4)_2S$
Reprec by HCl
$SnCl_4+HgCl_2$ =No reaction (different from stannous)

NOTE.—Metallic Zn added to a solution of stannic or stannous acidulated with HCl, will cause a deposit of metallic tin to take place. Action is hastened by using a piece of platinum foil with the Zn underneath it and applying heat. The deposit may be recognized by removing the undissolved Zn.

### **Mercury,** Hg. $HgCl_2$, sol in HCl (dil.)

$HgCl_2+H_2S$ $=HgS+2HCl$, sol. in aqua regia, insol in $(NH_4)_2S$ or acids.
$HgCl_2+SnCl_2$ $=2HgCl+SnCl_4$
(w)
$HgCl_2+2NH_4OH$ $=NH_2HgCl+NH_4Cl+2H_2O$ Different from Hg
(w) (ous)
$HgCl_2+2KI$ $=HgI_2+2KCl$. Different from Hg (ous)
(r)
$HgCl_2+HCl$ =No reaction. Different from Hg (ous)

NOTE.—Dip a clean penny in the solution and observe.

### **Iron,** Fe (ous) $FeSO_4$, sol in $H_2O$

$FeSO_4+2NH_4OH$ $=Fe(OH)_2+(NH_4)_2SO_4$
(gr)
$3FeSO_4+K_6(Fe(Cn)_6)_2=Fe_3(Fe(CN)_6)_2+3K_2SO_4$ "Turnbull's blue"
(dark blue) (Different from ferric)
$FeSO_4+KCNS$ =No reaction. (Different from ferrics.)
$FeSO_4+K_4Fe(CN)_6$ $=K_2Fe(Fe(CN)_6)+K_2SO_4$
(light blue)

### Iron, Fe (ic). $FeCl_3$, sol. in water

$FeCl_3+3NH_4OH = \underset{(r)}{Fe(OH)_3}+3NH_4Cl$. $Fe(OH)_3$, sol. in acid

$2FeCl_3+H_2S = 2FeCl_2+2HCl+S$. S separates out.

$4FeCl_3+3K_4Fe(CN)_6 = Fe_4(Fe(CN)_6)_3+12KCl$. (Prussian Blue)

$FeCl_3+K_6(Fe(CN)_6)_2$ = No reaction (Different from ferrou

$FeCl_3+3KCNS = \underset{(r)}{Fe(CNS)_3}+3KCl$

$2FeCl_3+3(NH_4)_2S = \underset{(b)}{2FeS}+6NH_4Cl+S$

Note.—b = black gr = green
br = brown o = orange
w = white r = red

### Chromium, Cr''. $KCr(SO_4)$, sol. in $H_2O$

$KCr(SO_4)_2+3NH_4OH = \underset{(gr)}{Cr(OH)_3}+K(NH_4)_3(SO_4)_2$. Sol. in acids. No reaction presence organic su stances

$KCr(SO_4)_2+3KOH = \underset{(gr)}{Cr(OH)_3}+2K_2SO_4$. Sol. in excess, reprec. boiling or adding $NH_4Cl$

### Fuse.—$KCr(SO_4)_2$ Solid,—in platinum crucible

$2KCr(SO_4)_2+2Na_2CO_3+6NaNO_3 = 2Na_2CrO_4+3Na_2SO_4+K_2SO_4 +6NO_2+2C$

Dissolve fusion, $H_2O$, acidulate, $HC_2H_3O_2$, boil = p = $PbCrO_4$ w addition of $Pb(C_2H_3O_2)$.

*Salt* *Reagent* *Reaction*

$2K_2CrO_4+3H_2S+10HCl = \underset{(gr)}{2CrCl_3}+4KCl+8H_2O+3S$. Note colo

$K_2Cr_2O_7+3H_2S+8HCl = 2CrCl_3+2KCl+7H_2O+3S$

$KCr(SO_4)_2+3(NH_4)_2S+6H_2O = \underset{(gr)}{2Cr(OH)_3}+K_2SO_4+3NH_4)_2SO_4 +3H$

### ALUMINIUM, Al. $AlCl_3$, sol. in $H_2O$

| | | |
|---|---|---|
| $AlCl_3+3HN_4OH$ | $=Al(OH)_3+NH_4Cl$.<br>(w) | $Al(OH)_3$, sol. in HCl<br>$Al(OH)_3$, sol. in KOH |
| $AlCl_3+3KOH$ | $=Al(OH)_3+3KCl$,<br>(w) | Sol in excess KOH<br>Rep. by $HCl+NH_4OH$ to alk.+boil |
| $2AlCl_3+3(NH_4)_2S$ | $=HNH_4Cl+Al_2S_3$ | |

### NICKEL, Ni. $Ni(NO_3)_2$, soluble in $H_2O$

| | | |
|---|---|---|
| $Ni(NO_3)_2+(NH_4)_2S$ | $=NiS+NH_4NO_3$<br>(b) | Insol in HCl (cold) |
| $Ni(NO_3)_2+2KCN$ | $=Ni(CN)_2+2KNO_3$<br>(gr) | Sol in excess of reagent<br>Rep. by HCl |

$Ni(NO_3)_2$+Dimethylglyoxime in sol made alk. with $NH_4OH$, acidify with $HC_2H_3O_2$

### COBALT, $Co''$. $Co(NO_3)_2$, sol. in $H_2O$

| | | |
|---|---|---|
| $Co(NO_3)_2+(NH_4)_2S$ | $=CoS+2NH_4NO_3$<br>(b) | Insol. in HCl.<br>Crystal of $KClO_3$ in sol.+heat causes decomposition |
| $Co(NO_3)_2+2KCN$ | $=Co(CN)_2+2KNO_3$. | Sol in excess, but sol. turns yellowish green. Rep in HCl |

NOTE.—Evaporate sol of cobalt in dish and note change from pink to blue.

$$Co(NO_3)_2+7KNO_2+2HC_2H_3O_2=K_3Co(NO_2)_6+2KC_2H_3O_2+2KNO_3+NO+H_2O$$

### MANGANESE, $Mn''$. $MnSO_4$, Soluble in $H_2O$

| | | |
|---|---|---|
| $MnSO_4+(NH_4)_2S$ | $=MnS+(NH_4)_2SO_4$.<br>(pink) | Sol. in acids<br>(Different from Zn) |
| $MnSO_4+H_2S$ | =No p in the presence of $HC_2H_3O_2$, MnS being soluble in it (Diff. from Zn ) | |
| $MnSO_4+2KOH$ | $=Mn(OH)_2+K_2SO_4$. | Insol. in excess of KOH, p changes to brown on exposure to air, becoming Mn $(OH)_3$ |

### Zinc, Zn. $ZnSO_4$, Soluble in $H_2O$

$ZnSO_4+(NH_4)_2S = ZnS+(NH_4)_2SO_4$. Sol. in acids (mineral Insol. in acetic acid.

$ZnSO_4+H_2S$ = Same as above

NOTE —In acid solutions no p is formed, in neutral, a partial owing to acid being formed during the reaction.

$ZnSO_4+2KOH = Zn(OH)_2+K_2SO_4$. Sol in excess of KOH- (different from Mn)

$2ZnSO_4+K_4Fe(CN)_6 = Zn_2Fe(CN)_6+2K_2SO_4$

### Calcium, Ca. $CaCl_2$, Soluble in $H_2O$

$CaCl_2+H_2SO_4 = CaSO_4+2HCl$. (white) Forms immediately in stron solutions In weak so boil, p. forms slowly

$CaCl_2+(NH_4)_2CO_3 = CaCO_3+2NH_4Cl$. (white) Sol in $HC_2H_3O_2$

$CaCl_2+K_2CrO_4$ = No reaction (Different from Ba, Sr)

$CaCl_2+(NH_4)_2C_2O_4 = CaC_2O_4+2NH_4Cl$ Sol in acids Insol. in $NH_4OH$

### Barium, Ba. $BaCl_2$, Soluble in $H_2O$

$BaCl_2+(NH_4)_2CO_3 = BaCO_3+2NH_4Cl$. (white) Sol. in $HC_2H_3O_2$

$BaCl_2+H_2SO_4 = BaSO_4+2HCl$ (white) Insol.

$BaCl_2+K_2CrO_4 = BaCrO_4+2KCl$. Insol in $HC_2H_3O_2$ (diff from Ca and Sr)

### Strontium, $Sr''$. $Sr(NO_3)_2$, Soluble in $H_2O$

$Sr(NO_3)_2+(NH_4)_2CO_3 = SrCO_3+2NH_4NO_3$. (white) Sol. in $HC_2H_3O_2$

$Sr(NO_3)_2+H_2SO_4 = SrSO_4+2HNO_3$. (white) Reaction more rapid i heated

$Sr(NO_3)_2+K_2CrO_4 = SrCrO_4+2KNO_3$ Sol. in $HC_2H_3O_2$ (diff from Ba, Ca)

### AMMONIUM, $NH_4$ $NH_4Cl$, Soluble in $H_2O$

$NH_4Cl$ + Heat on Pt foil = volatilization
$NH_4Cl$ + $KOH$ + heat = odor $NH_3$ Turns litmus blue
$NH_4Cl$ + $CaO$ (lime) rubbed in mortar = $NH_3$ gas
$NH_4OH$ + $HCl$ fumes = cloudy vapor

### POTASSIUM, K. KCl, Soluble in $H_2O$

$KCl$ + heat on Pt. = Does not volatilize with heat (Diff. from Am)
$2KCl + PtCl_4 = K_2PtCl_6$. (yellow) Flame test, violet

### SODIUM Na′. NaCl, Soluble in $H_2O$

Flame test, yellow.

### MAGNESIUM, Mg″. $MgSO_4$, Soluble in $H_2O$

$MgSO_4 + 2NH_4OH = Mg(OH)_2 + (NH_4)_2SO_4$. Sol. in $NH_4Cl$
(white)
$MgSO_4 + Na_2HPO_4 = MgNH_4 + (NH_4)_2SO_4$

NOTE —It is necessary to have an excess of $NH_4OH$ in this in order to render $MgNH_4PO_4$ insoluble; and the presence of $NH_4Cl$ is required to prevent the $NH_4OH$ from throwing down a white precipitate of $Mg(OH)_2$.

## Group Separation and Analysis

Substances to be Analyzed, in Solution *Basic Residues*.

| | | *Metallic Groups* | *Group Reagents* |
|---|---|---|---|
| GROUP | I. | Ag, Pb, Hg, (ous) | $HCl$ |
| | II | Cu, Pb, Hg, (ic), Cd, Bi, Sb, As, Sn. | $H_2S$ |
| | III. | Fe, Cr, Al, Co, Ni, Mn, Zn. | $NH_4OH$, $H_2O$ |
| | IV. | Ba, Ca, Sr.. | $(NH_4)_2CO_3$ |
| | V. | Mg | $Na_2HPO_4$ |
| | VI. | Na, K, $NH_4$ | |

GROUP I Solution + $HCl$ = $p_1$—$AgCl$,—$PbCl$,—$HgCl$ (ous),—$f_1$— Other groups (save).
$p_1$— + boiling $H_2O$ + filter + wash = $p_2$, — Ag, Hg, $f_2$ — Pb,
$p_2$— + $NH_4OH$ (warm + filter = $p_3$ — Hg black $f_3$ — Ag . . . Hg (ous)
$f_2$ — Confirmation + $HC_2H_3O_2$ to acid + $K_2CrO_4$ (yellow) $p_4$ . Pb
$f_3$ — Confirmation + $HNO_3$ = $p_1$ (white) . . . . . . . . . . Ag

**Group II.** Solution, $(f_1)+NH_4OH$, to alk. $+HCl$, to acid (disreg
any precipitate that may form), warm $+H_2S$ to satu
tion $+$filter$+$wash $= p_1$ and $f_2$.
$p_1 = CuS, PbS, HgS$ (ic), $Bi_2S_3, SnS, CdS, Sb_2S_3$, A
Sulfids
$f_2 =$ Other groups (save), (A) (B
$p_1+(NH_4)_2S = p_2 - CuS$, $CdS$, $Bi_2S_3$, $PbS$, $f_3 - Sb$
$As_2S_3$, $SnS$.
$p_2+$wash, place in evaporating dish, cover with H
(d) $+$heat, dilute with $H_2O+H_2SO_4$ (a little),
filter, wash $= p_3$ and $f_4$.
$p_3 = (HgS, PbSO_4), +HC_2H_3O_2+NH_4OH$ (excess), b
filter $= p_4$ and $f_5$.
$p_4 = $ (Hg, ic,), confirmation, $+$aqua regia, evapor
dilute $+SnCl_2 = p_5$, $-$ (white), Hg .........**Hg**

(A) $f_5 = (Pb)+HC_2H_3O_2+K_2CrO_4 = PbCrO_4$ ..........
**Copper** $f_4 = (Bi, Cu, Cd)+NH_4OH$, to alk. boil, filter $= p_6$ an
**Group** $p_6 = (Bi)+HCl$ (small amount) $+H_2O$ (large amt.) $=$
**Bi**
$f_5 = (Cu, Cd)$, separate into two parts, A and B $= Af_5 -$
$Af_5 = +HC_2H_3O_2+K_4F(CN)_6 = p_8$, (choc. colored)
$Bf_5 = +KCN$ to disappearance of blue $+(NH_4)_2S$
(yellow) . . . . . . . . . .
$f_3$ $+HCl$ to acid $= p_1$ (sulfids) and $f_4$ (discard).
$p_1$ $+(NH_4)_2CO_3$, stir, filter $= p_2$, **Sb, Sn,** $f_6$, $-$As.

(B) $f_6$ $+HCl$ to acid sol boil, p (yellow) $As_2S_3$ . .
Arsenic $p_2$ $+HCl$ (h) $+H_2O$, filter (if necessary), Zn (sheet)
Pt. foil, in sol. (fg), after short time remove
Let Zn remain. Stain on Pt foil shows .
Remove Zn from sol , rinse off into dish contain
sol. settle, decant, wash once by decantatio
HCl (h), dilute (slightly), if not clear, filter,
$HgCl_2$ (h), white p, shows.. ............

Note.—The sulfids of the Arsenic Group are yellow, orange, brown; a white or dirty gray precipitate, obtained by acidifying w HCl indicates a separation of sulfur only.

**Group III.** Iron Group, — Fe, Cr, Al and Zinc Group,—Co, Ni, Mn, Zn in $f_2$ from Group II.

$f_2$ $+NH_4OH=p_1$, (Fe, Cr, Al) $-f_3$, (Co, Ni, Mn, Zn)

$p_1$ in beaker$+H_2O+Na_2O$, (1 gm. about), stir, heat to remove excess of oxygen), dilute, filter, divide $f_4$ into two parts, (A) and (B), $p_2$ (Fe) $-f_4-$(Al, Cr).

$p_2+HCl$ (h)$+H_2O+K_4Fe(CN)_6$, few drops, p, (blue), shows **Fe.**

(A) $f_4$ $+HCl$ (acidify)$+NH_4OH$ (to alk ), boil, −p, (colorless), Al.

(B) $f_4$ $+HC_2H_3O_2$, boil$+Pb(C_2H_3O_2)_2$, −p (yellow) − (gelatinous) Cr.

**Zinc Group.**—Co, Ni, Mn, Zn$=f_3+H_2S=$p (sulfids) and $f_7$ (Save).

$p_1+HCl$ (very dilute), stir, filter, wash$=p_2$ (Ni, Co) $f_4$ (Mn, Zn).

$p_2$ Test with borax bead Dissolve in aqua regia, evaporate nearly to dryness, dilute, make alk. with NaOH, acidify with $HC_2H_3O_2$, divide into parts, (A) and (B), $f_5$.

(A) $f_5$ +few drops of di-methylglyoxime$=$p (red), shows. Ni.

(B) $f_5$ $+KNO_2=$p, $K_3Co(NO_2)_6$ . . . . . . . . . . . . Co

$f_4$ +boil to absence of odor of $H_2S$, if turbid add few crystals of $KClO_3$, boil to oxidize sulfur, cool, +Na OH to alk., stir, filter, wash$=p_3$ (Mn), $-f_6$(Zn).

$p_3$ Fuse with $Na_2CO_3$ and $NaNO_3$ on Pt foil, bluish green .. .. .......... .......... ..... .Mn

$f_6$ Acidify with $HC_2H_3O_2+NaC_2H_3O_2$ (about 1 gm.) heat to boiling, $+H_2S=$p (white), shows... ..Zn

**Group. IV.** **Barium Group.**—Ba, Sr, Ca, in $f_7$ from Zinc Group.

$f_7$ $+(NH_4)_2CO_3=p_1$ (Ba, Ca, Sr), and $f_8$ (Save).

$p_1$ Examine by flame test and spectroscope. $+HC_2H_3O_2$ (h), $+H_2O+K_2CrO_4$ (excess), warm, filter, $p_2$ (Ba), and $f_9$ (Ca, Sr).

$p_2$ (Yellow) shows. ..........................
$f_9 + H_2O + H_2SO_4$ (few drops), boil, filter $= p_3$(Sr) an
(Ca).
$p_3$ (white) shows.... .................. ..
$f_{10} + NH_4OH$ to alk. $+ (NH_4)_2C_2O_4 = p$ (white) ...

Note.—The Strontium precipitate is likely to form slowly.

Group V. **Potassium Group.—Mg, K, Na, $NH_4$, in $f_8$, from Bar Group.**

$f_8 + Na_2HPO_4$, filter $= p_1$ (white) indicates....... ..
$f_{11}$ Test for K only. Evaporate to dryness, heat o foil to absence of fumes, test by spectroscope fo Test another portion of residue on pt foil a heating, foil and all in a very little water, ad drop or two of HCl, when sol is complete, pou watch glass, add few drops of $PtCl_4$, and a l alcohol and stir. A yellow p shows **K**.

Note.—Ammonium compounds $+ KOH +$ heat $=$ ammonium fu for Na see flame tests.

BANGALORE

## Acid Residues

*Preliminary Tests.*—In carrying out tests for a residues, salts and acids, always acidify with HCl a boil before adding $BaCl_2$, in testing for a sulfate.

Likewise acidify with $HNO_3$ and boil before test with $AgNO_3$ for any of the halogen group.

In case of a yellow precipitate produced by AgN indicating iodine or bromine compounds, remove all metals of the upper groups before attempting the se ration of the I or Br. Therefore boil with an excess $Na_2CO_3$, filter, reject the precipitate, neutralize w $HNO_3$, boil until $CO_2$ is removed, make slightly alkal with $NH_4OH$, then proceed as directed in the separat of mixed iodids, bromids, and chlorids.

Solids soluble in HCl may be tested for the chlorid by fusing with "fusion mixture," dissolving fusion in hot water, filtering, acidifying filtrate with $HNO_3$, boiling, filtering if necessary, and adding $AgNO_3$ to filtrate.

SULFATES.—$SO''_4$. $(NH_4)_2SO_4$, sol. in $H_2O$.

| *Reagent* | *Reaction* |
|---|---|
| $(NH_4)_2SO_4$ | $+ BaCl_2 = BaSO_4 + 2NH_4Cl$. Insol. in any reagent. (white) |

NOTE.—When testing an unknown sol. for sulfates, acidify with HCl, and boil first. If Ag, Pb, Hg, be present, use $Ba(NO_3)_2$ instead of $BaCl_2$, also acidify with $HNO_3$ instead of HCl. Otherwise chlorids of the above metals would be precipitated.

### *Test for Solid Sulfur Compound*

Compound$+Na_2CO_3+$mix and fuse on charcoal, using reducing flame, remove mass, moisten, place on silver coin, black spot shows $Ag_2S$.

### *Test for Free Sulfuric Acid*

Solution+small amount of sugar, evaporate to dryness, black residue due to the charring effect of the $H_2SO_4$.

Paper dipped in solution of $H_2SO_4$ turns black.

CARBONATES, $CO''_3$. $Na_2CO_3$, sol. in $H_2O$

Mineral acids cause effervescence, due to the formation of $CO_2$ gas.

$$Na_2CO_3+2HCl=2NaCl+H_2CO_3=CO_2+H_2O.$$

### *Test for* $CO_2$ *Gas*

Fill a test-tube one-half full of lime water, (fresh introduce freshly generated $CO_2$ gas into the limewater, white pellicle of $CaCO_3$ will be formed on the surface the limewater.

### *Free Carbonic Acid Exists Only*

Free carbonic acid gas exists only in aqueous solution and is decomposed by heat into $CO_2$ and water. Ther fore boil the solution, conduct the steam by tube int fresh limewater, a white precipitate shows the presen of $H_2CO_3$. Blow through a piece of glass tubing int fresh limewater a white precipitate is formed, $CaCO_3$.

### SULFIDS, S. FeS, sol. in acids, HCl, or $H_2SO_4$.

$FeS+2HCl=H_2S$ (gas)$+FeCl_2$ (with effervescence HCl will produce effervescence of $H_2S$ from nearly a sulfids.

### *Test for* $H_2S$

Smell, turns $Pb(C_2H_3O_2)_2$ black.

$FeS+(NH_4)_2S=$ turns silver compounds blac $Pb(C_2H_3O_2)_2$ treated with soluble sulfids turns black.

### SULFITES, $SO''_3$. $Na_2SO_3$, (sol. in water)

$Na_2SO_3+HCl+$heat$=SO_2$ fumes. Those will also tur $K_2Cr_2O_7$ green (use glass rod moistened with $K_2Cr_3O$ Hold in $SO_2$ vapor, the drops of $K_2Cr_2O_7$ will turn green

### *Test for Free Sulfurous Acid*

Same as sulfites. Odor of $SO_2$. Also turns $K_2Cr_2O$ sol. green.

### NITRATES, $NO_3$. $NaNO_3$, (sol. in $H_2O$)

To $NaNO_3$ add $H_2SO_4$, mix cool, in test-tube. Incline tube, pour in $FeSO_4$, strong solution, carefully. It will float on top, forming a brown ring at line of separation. This ring is characteristic of a nitrate. If the solution is weak it takes some time for the ring to form.

### *Free Nitric Acid Test*

Sol.+$FeSO_4$=dark colored ring

### *Analysis of Gunpowder*

Boil sample in water, test for nitrate in filtrate. Dry p, treat with $CS_2$, test for S. Evaporate to dryness, ignite residue, note smell and action on $K_2Cr_2O_7$, test for C, black residue left on filter paper is carbon.

### CHLORIDS, Cl. $NH_4Cl$, (sol. in $H_2O$)

Sol., $AgNO_3$ gives a white p, AgCl, sol. in $NH_4OH$. From this it is again p'd by $HNO_3$.

NOTE.—When testing for chlorids, cyanids, bromids, or iodids acidify with $HNO_3$ before adding $AgNO_3$.

### *Test for Free* HCl

HCl+$MnO_2$ gives of chlorine gas and bleaches litmus paper. Also sol.+$HNO_3$=white p, sol. in ammonia, reprecipitated by $HNO_3$.

### CYANIDS, CN. KCN, (soluble in $H_2O$)

KCN+$NH_4OH$ to alk. sol.+$(NH_4)_2S$ to slight excess, filter, heat filtrate to drive off $(NH_4)_2S$ fumes, acidify with $HCl$+a drop or so of $FeCl_3$, blood red p. indicates $KCN$.

$KCN+AgNO_3$=white p soluble in $NH_4OH$, reprecipitated with $HNO_3$.

### Bromids, Br. KBr, (sol. in water)

Sol.+$AgNO=AgBr$ (yellow) p, slowly sol. in am. heat, reprecipitate in $HNO_3$.

Sol.+Chlorine water+shake. Bromine is liberated.

$$KBr+Cl=KCl+Br.$$

Add a few drops of chloroform to the above and shake; the color will change to reddish brown.

### Iodids, I. KI, (sol. in $H_2O$)

$KI+AgNO_3$=p (yellow). Insoluble in $NH_4OH$.

$KI$+cold starch solution+chlorine water, (blue) p.

$KI+AgNO_3+H_2SO_4$ (*c*)=iodine vapor.

A glass rod moistened with starch solution held in a vapor of iodine will turn blue.

$KI$+Chlorine water shaken with $CS_2$ turns violet.

### *To Determine Chlorids, Bromids, and Iodids mixed*

Solution+heat+$Cu_2SO_4$ (made by mixing $FeSO_4$ +$CuSO_4$)=I as CuI. If I is present, filter, test for complete precipitation, make filtrate alk. with KOH, evaporate to dryness, mix dry residue with twice its bulk of $K_2Cr_2O_7$. Place into dry distilling flask+$H_2SO_4$+heat and conduct the evolved gas into water contained in another flask. Divide water into two parts—test one with $CO_2$ for Br; test two with $NH_4OH$ (excess)+$HC_2H_3H_2$ to acid reaction+few drops of $Pb(C_2H_3O_2)_2$, (yellow) p shows chlorine.

*Equations.*

$2CuSO_2+2FeSO_4=Cu_2SO_4+Fe_2(SO_4)_3.$
$CuSO_4+2KI=Cu_2I_2+K_2SO_4.$
$6KBr+K_2Cr_2O_7+11H_2SO_4$
$=3Br_2+Cr_2(SO_4)_3+8KHSO_4+7H_2O.$
$4KCl+K_2Cr_2O_6+6H_2SO_4$
$=2CrO_2Cl_2+6KHSO_4+3H_2O.$
$CrO_2Cl_2+2H_2O=H_2CrO_4,+2HCl.$

### PHOSPHATES, $PO_4$. $Na_2HPO_4$, (sol. in $H_2O$)

$Na_2HPO_4+NH_4HMoO_4=$ (yellow) p. granular, appears on shaking; easily soluble in alk. solutions.

*Reaction.*—$Na_2HPO_4+12NH_4HMoO_4+11HNO_3$
$=(NH_4)_3PO_4(MoO_3)_{12}+2NaNO_3+9NH_4NO_3+12H_2O.$

NOTE.—Arsenates also give a yellow p with this reagent only on boiling.

$Na_2HPO_4+NH_4Cl+$alk. with $NH_4OH+MgSO_4$ gives (white) p.

$MgNH_4PO_4$, soluble in acids. (This is only of value in the absence of arsenate).

### BORATES, B″. $Na_2B_4O_7$. (sol. in $H_2O$).

Place *solid sample* in evaporating dish, moisten with $H_2SO_4$ (*c*)+a little alcohol, set fire. Burns with a green edge flame.

*Reaction.*—$Na_2B_4O_7+H_2SO_4+12C_2H_5OH=$
$4(C_2H_5)_3BO_5Na_2SO_4+7H_2O.$

*Liquid Sample.*—Evaporate to dryness and test as above. If Cu or Ba be present, remove first.

*Free Boric Acid.*—$H_3BO_3$. White solid. Soluble in water; turns litmus red; moisten with alcohol. It burns with a green edge flame.

### FLUORIDS, F′. $CaF_2$ (sol. in acids, conc.)

Coat the convex side of a watch glass with wax, an trace a design in the wax. Place some powdered CaF in a porcelain crucible, moisten it thoroughly with $H_2SO_4$ cover crucible with the watch glass; design exposed to th fumes for two or three hours will be etched on the glas

### FERRO-CYANIDS, $K_4Fe(CN)_6$, (sol. in $H_2O$)

Solution+$FeCl_3$ =p (Prussian blue).
Solution+$CuSO_4$ =p (Chocolate brown).
Solution+$FeSO_4$ =p (Light blue).

*Reactions*:

$K_4Fe(CN)_6+FeCl_3 = Fe_4(Fe_4(CN)_6)_3.$
$K_4Fe(CN)_6+CuSO_4 = Cu_2(Fe(CN)_6).$
$K_4Fe(CN)_6+FeSO_4 = FeK_2(Fe(CN)_6).$

### FERRI-CYANIDS, $K_6(Fe(CN)_6)_2$, (sol. in $H_2O$)

Solution+$FeSO_4$= (dark blue)

### SULFO-CYANIDS, KCNS (sol. in $H_2O$)

Solution+$FeCl_3$=$Fe(CNS)_3$, p, (blood-red).

### SILICATES

If a silicate in solution be acidified with HCl+evaporated to dryness, silica will separate out as $SiO_2$, may be filtered out of the aqueous solution of the dry mass.

NOTE.—After evaporating to dryness moisten with HCl (*c*). Let stand a few minutes, add $H_2O$ (h), stir, filter.

Take ½ gram of some insoluble silicate i.e., clay, pulverize, fuse with four times its bulk of mixture of equal parts of $K_2CO_3$ and $NaNO_3$, cool, boil with $H_2O$, filter, examine the filtrate for $SiO_2$.

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